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## Effects Produced by Varying Types of Drying on Starch Coated Paper Properties and Binder Migration

Mark J. Schaefer  
*Western Michigan University*

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EFFECTS PRODUCED BY VARYING TYPES  
OF DRYING ON STARCH COATED PAPER  
PROPERTIES AND BINDER MIGRATION

by

Mark J. Schaefer

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## ABSTRACT

The major concern of this report is binder migration and the factors which play a major role contributing to its presence. The major factors studied were coatings using varied drying methods, adhesive levels, % solids and types of starches.

Results obtained show that to obtain minimal migration coatings should be dried evenly throughout using infrared sources of heat.

Coating with different adhesive levels will vary optical and strength properties. Binder migration is more evident when using lower adhesive levels.

Coating at different % solids did not have any real significant effect in this study due to a very short span in the percentages used.

The major conclusion reached with using various types of Penford Gums is that of viscosity. The higher the viscosity the less overall migration taking place in the coating.

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## INTRODUCTION

Binder migration has been under study for many years. Binder migration will play a major role upon the properties exhibited by the coating.

The use of starches, latex or casein in coating formulation is common practice. Good printing properties may be achieved by using any of the binders, however, cost difference and particular property requirements such as high wet rub resistance or gloss dictate the use of a particular binder.

Many studies have been made on the most common coating system, clay-starch. The effects of drying rates on binder migration and coating properties have been evaluated thoroughly in the use of two starch and latex systems.

Binder migration is said to follow along the same path as that of water as it is removed during drying of the coated sheet. Different types of drying affect the path of water removal and, thus, the direction and extent of binder migration. Drying is the primary coating variable which will be considered in this study. Other factors include pigment particle size, solids content, pore size and distribution of substrate, initial adhesive ratio, and the effective viscosity of the binder.

The results obtained relating coating properties to binder migration as affected by drying conditions may give a better understanding of the complex cause and effect relationships involved. It might also give a better understanding of binder migration and some means with which to prevent the harmful effects it causes and to maximize benefits of migration.

## HISTORICAL BACKGROUND

### Binder Migration

The mechanism of binder distribution is thought to involve primarily capillary competition for the vehicle between the substrate and the coating but is also influenced by drying. Eames (1) studied transverse tensile strength (TTS) as a function of binder migration. TTS was defined as the tensile stress required to cause failure in a shell-like specimen when uniformly distributed stress was applied perpendicular to the plane of the specimen. Different types of drying conditions and various substrates were used to determine drying effects on TTS and binder migration.

Another study by Heiser and Cullen (2) concerned itself with the effects of drying rates on latex coating properties and adhesive redistribution. Other studies have been made using different adhesive and varying the rates and types of drying. (3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14)

### Coating Variables Studied

Binder migration is said to follow the path of water movement in the sheet. The variables which will affect the degree and extent of water movement and thus binder migration are:

- A) Substrate Pore Size
- B) Particle Size of Pigments and Latex
- C) Initial Adhesive Ratio and Solids Content
- D) Methods of Drying
- E) Coat Weight

#### A) Substrate Pore Size

There is a commonly accepted theory that binder migration follows the same pattern as water flow within the pigmented coating before the coating loses enough water to become immobilized. Different types of substrate would absorb water differently due to varying effective pore size and pore size distribution. Pore size is affected by surface size, by the fiber and filler component and by sheet formation variables. Surface wettability is affected primarily by internal sizing additives.

Some types of substrates which have been studied were aluminum foil (1), Millipore filter (1), paper (2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13), paperboard (2, 5). Some conclusions reached may be summarized as follows; with other factors being equal, a coating applied to a substrate with small pores lost more adhesive to the substrate and exhibited lower TTS than did the same coating applied to a substrate with larger pores. (1) This was explained by Eames (1) as follows; "It is suggested that the major loss of adhesive to the substrate occurs in the saturated state of flow and that low rates of penetration favor the maintenance of this type of flow, even to the extent that a greater volume of vehicle penetrates a substrate of small pore size than it does a substrate of large pore size." However Heiser (2) found there was no significant change in the rate of migration to the substrate when using either paper or paperboard. This may be attributed to other variables which overshadowed any difference in pore size.

#### B) Particle Size of Pigments and Latex

Pigment size will determine how much penetration into the raw stock the starch will have. Decreasing the pigment size will usually increase TTS because of the coatings better ability to penetrate the pores and capillaries of the substrate. Smaller flaws with smaller particles would also tend to give higher TTS values.

The results on foil (1) showed that TTS was independent of pigment particle size, whereas on a porous substrate TTS increased with decreasing particle size. For coatings on foil, migration due to drying can proceed only away from the foil-coating interface and toward the coating-air interface (the coating surface.) Since migration of binder was toward the coating interface, failure should be at the foil interface due to a depletion of binder at the foil coating interface.

On using two different particle size latexes, Heiser (2) found that small particle size latex seemed to migrate slightly more than the larger particle size latex. Greater migration was attributed to the greater mobility of the smaller particles. Also, a smaller particle size has a greater number of particles present in a given volume of coating.

#### C) Initial Adhesive Ratio and Solids Content

The amount of adhesives in the coating system is an important factor in binder migration. The primary purpose of the adhesive is to bind the pigment particles together and to anchor the coating to the surface of the raw stock. (3) TTS increased when the adhesive content was increased. "TTS may be directly proportional to the final adhesive ratio for clay-starch coatings or fail when the adhesive distribution is uniform." (1) For a given adhesive ratio,



TTS was greater for Millipore filter coatings than for foil coatings. The reason given was that in the coating on Millipore filter the adhesive had a chance to migrate into the substrate whereas an aluminum foil migration was stopped at the foil-coating interface and the rest of the migration was toward the surface of the coating. Increasing the initial adhesive ratio allowed more adhesive to penetrate into the substrate providing for a stronger coating. Eames (1) concluded that replacement of starch by clay, volume for volume, weakened the coating. The higher the adhesive level used the stronger the coating should be.

Heiser (2) concluded that the prime factor governing binder migration was the solids content of the coating formulation, high solids coatings were less prone toward binder migration than low solids coatings.

#### D) Methods of Drying

In coatings containing starch there is a critical setting time, after which binder migration is limited. This critical setting time is due to drying of the coating before it reaches the actual drying section. This is where drying rates become important. Binder migration is considered to be a function of drying rate. (5) One of the critical conditions in drying is the balance between the rate of liquid phase flow from the coating into the base sheet and the rate of evaporation. (6) Binder migration may follow the same pattern. It may result due to penetration of the liquid into the raw stock, or it may migrate with the water in the coating upon drying, namely evaporation.

Location of water in a coated sheet does not seem to effect the

drying rate behavior to a measurable extent. It is generally understood that binder migration follows the same pattern as water flow within the pigmented coating before the coating loses enough water to solidify. (2) Eames (1) studied drying of coating with a hot air blast provided by a home-type hair drier, and by natural convection. The hot air blast was at 200°F for one minute on Millipore filter and for two minutes on foil. Natural convection drying was at 73°F.

Increasing the rate of drying reduced the TTS of coatings both on Millipore filter and aluminum foil. The coating on foil lost a much larger portion of its TTS than did the coating on Millipore filter. Apparently the porous substrate competed with the capillary forces generated by the drying action. Blast drying of coatings on Millipore filters gave coatings containing significantly more of their original adhesive than did coatings dried more slowly. The layers near the surface of the coating on Millipore filter appeared to be strengthened by blast drying, indicating that part or all of the increased starch retention was in the surface layers.

The plane of failure during TTS determinations correlated very closely with the known adhesive distributions regardless of the drying method.

The blast-dried coatings were much more brittle than the air-dried, increased starch concentrations at the two surfaces of the coating was used to explain this brittleness, since thick films of starch are known to be brittle. The thinner the film of the more flexibility and toughness it exhibited (2). Further examination showed that the depth of starch penetration into the Millipore filter was less for blast dried coatings than for coatings dried by natural convection.

Some conclusions about drying drawn by Eames (1) were: When applied to a nonporous substrate, coatings dried with a hot-air blast had less TTS and failed nearer the substrate than coatings dried by natural convection at room temperature. When applied to a porous substrate, coatings dried with a hot-air blast retained more adhesive but had less TTS than coatings dried by natural convection at room temperature.

Heiser (2) varied the rates of drying with slow drying rate accomplished by coating at 100 fpm and drying at 200°F, and rapid rate drying by coating at 1000 fpm and drying at 500°F substrates used were 40 lb. paper and 175 lb. paperboard.

Some observations made from their study were that binder migration was toward base stock when a high solids coating was dried at a slow rate. Apparently the base stock absorbed enough water to cause the binder to follow into the substrate before migration to the air surface could occur.

Binder migration was towards both coating surface and the substrate when a high solids coating was dried rapidly. The high speed did not allow the coating to reach the critical setting time (time required for immobilization of coating layer) and the evaporation of water at the surface caused some migration to the coating surface.

Levels of binder migration of low solids coating dried at a low rate were found at both the coating surface and the fiber interface (2). The coating remained "open" long enough for binder migration into the substrate as it absorbed water and also to the coating surface through water evaporated at the coating surface during drying. A higher percentage of latex found at the coating surface verified that a larger quantity of water was removed from

the coating surface.

Heiser (2) found that adhesive migration was primarily toward the coating surface for a low solids coating applied under rapid drying conditions. The lower solids level of the coating allowed it to remain mobile long enough for rapid drying to cause a predominant surface migration.

Some general observation by Heiser (2) on coated paper and paperboard were as follows: (1) Binder migration toward the substrate was predominant in a high solids coating under slow drying conditions.

(2) Binder migration of a high solids coating applied under rapid drying conditions was toward both the coating surface and substrate. The quantity of binder at the surface of coating on paper and paperboard was almost equal.

(3) Binder migration of a low solids coating applied under slow drying conditions was toward both coating surface and substrate. Quantities of binder at the surface was greater for paper than that of paperboard.

(4) Binder migration of a low solids coating applied under rapid drying conditions was almost exclusively toward coating surface. Under these rapid drying conditions only a small amount of water was able to be absorbed by the paperboard. Most of the water was evaporated at surface of the coating.

Some thoughts on binder migration made by Heiser (2) were "that by knowing the forces moving the water from the coating we should be able to predict the direction of adhesive migration." The forces in his report which removed water were the base stock absorption and evaporation of water.

"The degree of water absorption by the substrate would depend on the degree of internal sizing, degree of surface sizing, porosity and makeup of the substrate. Another factor taken into account is whether the water absorbed by the substrate evaporates by passing through the substrate, or whether the water eventually evaporates through the coating. The amount and rate of water removed from the surface should depend on the speed with which the coated web reaches the ovens, and on the temperature, air velocity, and relative humidity of the ovens."

The prime factors controlling the direction of migration were the drying rates and absorbency of the coated stock. At slow drying rates, the direction of migration seemed to be primarily toward the substrate, while at fast drying rates, the direction of migration was toward the coating surface as well as toward the substrate. The degree of binder migration to the surface was proportional to the drying rate.(2)

Different types of drying which have been used in other studies are forced hot air, infrared heaters, and cylindrical dryers. When using forced hot-air at a slow rate, migration tended to be toward the base stock. (3) When lowering the hot-air rate in a drying process, binder migration to the coat surface was reduced. (7) Using high rate drying (rapid drying), the binder migration was toward the surface of the coating. Higher evaporation rates increase binder migration. (8) Binder migration toward the surface of the coating was strongest when exclusively applying hot-air drying at high air velocities. (7)

By using infrared heaters on both sides of the sheet, binder migration was essentially eliminated. (7) Infrared heaters provide

heat evenly on both sides of the sheet. Only minor evaporation occurred using infrared heaters because of its ability to heat the web evenly throughout. (9)

Cylindrical dryers provide mainly for drying due to evaporation. The bottom of the sheet is exposed to high temperature, the water nearest the cylinder is evaporated up through the sheet. When the sheet leaves the cylinder, some flash evaporation occurs through the base stock. Some of the binder migration will occur then but most of the binder migration would be toward the air-coating surface, due to the following of evaporated water leaving the coating surface.

#### E) Coat Weight

Eames (1) found that coatings on Millipore Filter revealed no significant effects on TTS due to variation in coat weight. On aluminum foil, though, TTS showed a strong dependence on coat weight. TTS was increased on thinner coatings. On porous substrates thick coatings tended to be weaker in TTS than thin coatings, and the failure occurred near the substrate instead of randomly.

## Effects on Coating Properties

Heiser (2) studied calendered gloss, ink absorbency, and glueability as properties of coated paper affected by binder migration.

Calendered gloss was said to have correlated well with binder migration. The high solids coatings gave better gloss than low solids. Gloss was also better for slow drying rates as compared with rapid drying rates.

By assuming that calendered gloss increases with increasing surface pigment concentration, and decreases with increasing surface binder concentration, the gloss values were seen to compare extremely well with results obtained by qualitative and visual analysis. (2, 14, 15)

Kalinski (14) used a special brush to generate gloss and said; "The mechanism of gloss generation is due to a redistribution and orientation of mobile polymer material available at the surface, rather than to an orientation of clay particles."

Ink receptivity was determined by K & N ink. The larger the percent drop in brightness, the more ink receptive the sample was. High solids coatings were more ink receptive than low solids. Coatings dried at a slow rate were more ink receptive than coatings dried at a rapid rate. Assuming that ink receptivity is a function of surface binder level, then correlation is obtained between the ink absorption test and the degree of binder migration.

Heiser (16) went into greater depth in another study using an electron microscope to actually view what is happening in this test. Since K & N ink test is a wipe off test, the micrographs produced indicated that K & N "absorption" is in reality a mechanical entrapment

in surface irregularities.

Glueability was rated as the time in seconds to achieve fiber tearing level, when tested face to face with an acetate glue. Samples glued faster when coated at low solids or rapid drying rates. Coatings with the least amount of binder at the surface gave the lowest contact angle and were the fastest gluers.

Heiser concluded that calendered gloss, ink absorbency and glueability decreased as the surface concentration of binder increased.



### EXPERIMENTAL APPROACH

The direction of water flow in a coating will determine to a certain extent the degree and direction of binder migration in that coating. Variables which will affect the amount and flow of the water in the coating are: (1) Substrate (2) Initial adhesive ratio (3) Pigment particle size (4) Drying rates (5) Solids content.

Factors which will be held constant during this study will be:

(1) Pigment type and size (2) Coat weight (3) Substrate (4) Formulation of coating.

Variables included in this study are:

(1) Adhesive particle size - using starches with different degrees of substitution.

(2) High and low solids coatings

(3) Drying rates A) Natural Convection

B) Oven drying

C) Infrared Lamp

D) Infrared Keegan Coater

(4) Adhesive level

Once the coating had been accomplished coating tests were run on the coated sheets. Tests used were: I.G.T. Pick, K & N Ink Holdout, Gloss after calendering, Sheffield Smoothness, Opacity and TTS.

The method being used for running TTS is as described in Eames article reference #1 page 4.

## COATING FORMULATIONS AND METHODS

The coating formulations were made at a 50% solids level. 100 parts of HT #2 predispersed clay were used along with 17 parts of Penford gum. The coating was then diluted to 50% solids with one of the 290 series being diluted to 45% solids level.

To change the adhesive levels 100 parts of clay were used along with 12, 15 and 18 parts of P.G.290 with the actual coating being done at 50% solids.

The cooking temperature of the starch was 205°F. The approximate viscosities of the batch cooked starches at 150°F using the Brookfield Viscometer were:

	P.G.290	P.G.290
12%	5 cps	
15%	10 cps	
17%	28 cps	775 cps
18%	38 cps	

The methods used for coating were the pilot machine Keegan coater, along with drawdown handsheets. One problem of using drawdown handsheets is that there is a time lapse of from 1 - 2 seconds before being placed under the desired drying conditions. Results are comparable though due to the same relative error being present in relative humidity, oven dry and infrared lamp samples.

The substrate used for all coatings was a 40 lb. basis weight sheet.

Drying rates were varied by using natural convection, oven and infrared methods of drying. Natural convection drying was

accomplished by hanging of the coated sheets in a room until dry. This method provides for slow drying of the sheet. Room temperature was 72°F with 50% relative humidity.

Oven drying was accomplished by hanging the coated sheets in an oven at 212°F. This would account for a medium rate of drying.

Infrared methods were used to accomplish fast drying. Two different types of infrared methods were used. The first using a pilot machine Keegan coater with infrared heating elements. Coating was accomplished at a speed of 40 fpm and at a temperature of 380°F.

Placing drawdown handsheets under an infrared lamp was the other method. Temperature of this lamp was 450°F.

Gloss tests were run on both calendered and uncalendered sheets, while the rest of the tests were run only on the uncalendered sheet.

# TEST RESULTS

The values in this table were obtained by averaging values of seven tests from seven different sheets of the same type of coating. TTS being the only exception, only three tests were run per type of coating.

TABLE NO. I Changes In Coating Properties When Varying Methods Of Coating And Drying

		250 50% Solids	Equal B.W. 290 50% Solids	290 45% Solids	Adhesive Levels Keegan Coater 50%	
Uncalendered Gloss (75°)	* R.H.	6.9	8.1	11.6	12	10.0
	O.D.	7.3	8.2	12.4	15	8.7
	I.R.	7.1	8.4	11.8	18	7.6
	K.C.	7.3	8.7	13.8		
Calendered Gloss (75°)	R.H.	43.2	43.3	51.9	12	51.0
	O.D.	39.8	45.7	50.8	15	46.3
	I.R.	39.8	46.0	49.2	18	44.6
	K.C.	37.9	46.3	50.6		
Opacity	R.H.	88.4	88.2	89.3	12	85.0
	O.D.	88.5	88.9	89.7	15	85.3
	I.R.	88.6	88.8	89.8	18	84.3
	K.C.	87.7	85.3	88.3		
K & N Ink (% drop)	R.H.	43.7	52.6	53.8	12	52.8
	O.D.	43.4	50.3	52.5	15	48.8
	I.R.	44.5	49.8	52.3	18	42.7
	K.C.	45.9	48.8	49.4		
I.G.T Pick (fpm)	R.H.	62	52	60	12	15
	O.D.	63	60	60	15	62
	I.R.	53	48	48	18	75
	K.C.	72	30	30		
Smoothness	R.H.	127	133	102	12	93
	O.D.	133	122	106	15	198
	I.R.	126	94	94	18	105
	K.C.	135	90	93		
TTS (lb/in <sup>2</sup> )	R.H.	1600	2800	300	12	5000
	O.D.	2000	4100	5700	15	4700
	I.R.	2600	4200	4200	18	4800
	K.C.	4500	4700	5000		

\*  
— R.H. Relative Humidity, Natural Convection Drying  
O.D. Oven Drying  
I.R. Infrared Lamp Drying  
K.C. Keegan Coater, Infrared Method Of Drying

## DISCUSSION OF RESULTS

250 vs. 290 (Table I Columns 1 and 2)

According to the manufacturer the good water-holding properties of the Penford Gums are responsible for decreased adhesive penetration into the substrate with a consequent decrease in coating failures due to adhesive "starved" areas in the coating layer. P.G. 250 is a medium viscosity starch, while P.G.290 is a low viscosity starch. The viscosity of the starch seems to have been an important factor in relating the amount of binder migration.

The gloss test run on the coated sheets show that P.G.290 will give higher gloss values than P.G.250. Since the clay particle size was not varied the difference in gloss values has to be due to the presence of binder at or near the surface of coating. Although there may be only one point difference on uncalendered sheets, the calendered sheets would tend to lend to the fact that binder in the P.G.250 was not very mobile and tended to migrate toward the surface more than P.G.290. P.G.290 being less viscous and of smaller particle size achieved more migration into the capillaries and voids of the substrate. P.G.290 having a lower viscosity would allow the clay particles to align themselves more easily at the surface than P.G.250.

Using the smoothness and K & N ink values in determining binder migration, it is shown that P.G.250 has more binder at surface than P.G.290. The less starch present at the surface of coating the less amount of penetration by oil used in K & N ink test. K & N ink test is a method of measuring the penetration

of an oil into the sheet. K & N ink value represent the % drop in brightness of a sheet. The more ink receptive the sheet is the higher drop in brightness occurs. According to these results more ink receptivity is achieved when using P.G.290 than P.G.250.

The strength tests, I.G.T. Pick and TTS, essentially give the same results. Although I.G.T. Pick gives results which show more binder present at surface in P.G.250 than in P.G.290, TTS will lend more toward the results obtained by drying rather than total migration at this point.

#### Types Of Drying (Table I Columns 1, 2 and 3)

When using the gloss values to evaluate types of drying it is shown that higher gloss values are obtained when using infra-red methods of drying. This is due to the ability of the infra-red heat being applied evenly throughout the sample, creating less binder migration. If any binder migration is to take place upon infrared heating it would procede toward the surface of the coating due to evaporation of water at surface, the heating elements being above the coated sheet. Oven drying and natural convection take longer for the coating to reach its critical setting time. Examples of time it takes the coating to lose its glossy surface for each type of drying are; Relative humidity  $2\frac{1}{2}$  - 3 minutes, Oven drying 10 - 12 seconds, Infra red lamp 2 - 4 seconds and Keegan coater 7 - 10 seconds. Critical setting time plays an important role in the amount of migration which is to take place. Once the substrate is satisfied the major way left for water to escape is through the coating surface. The larger the critical setting time the longer the binder has

a chance to migrate to the surface. As has been said before more adhesive at the coating surface will produce a duller gloss. Therefore according to values on the charts to table more migration of binder to surface has taken place when drying at a slower rate.

Upon evaluating the K & N ink values it becomes difficult to give a trend for binder migration. As the other test show advanced migration to the surface using slower methods of drying, K & N ink does not. One would expect with the increase of binder at the surface less ink penetration would occur.

If Heiser's (16) evaluation of surface irregularity is used it could explain what is happening. Oven drying is taking much longer to reach critical setting time than the other methods of drying. As water is being removed it would move along the path of least resistance in the coating. At first there would be no set path of removal but as some parts reach its setting time earlier than others, water would start being removed by set paths. As the remainder of the coating reaches its critical setting time these paths would remain as voids or surface irregularities in the coating.

Since K & N ink test involves wiping away of the testing ink, the ink that has not penetrated will fill the surface irregularities providing for a larger percent drop in brightness.

In evaluation of the strength tests it is shown that the slower methods of drying provide for binder migration toward the surface. I.G.T. Pick values will increase when more binder is present at surface to bond more tightly the clay particles, preventing their being removed from the coating surface by the tacky ink. According to I.G.T. Pick values slower rates of

drying provide for increased surface strength of the coating.

One of the problems with this test was that as the values neared the 100 range the paper itself would tear. So in effect this test measured only the surface coating strength and not the total coating strength which could have been higher due to substrate penetration of binder.

TTS is a measure of overall bonding strength of the coating. TTS values increase with even distribution of binder throughout the coating. TTS values decrease when large amounts of binder are present in one area and are lacking in another. According to this test more even distribution of binder is present in the infrared methods of drying. The slower drying rates give lower TTS values due to the increase in binder concentration in some areas and loss of binder presence in other areas.

#### % Solids Concentration (Table I Columns 2 and 3)

When coating at different solids levels one would expect an easier transfer of water and binder through the coating. According to the results obtained this is also proven. The tests run were on sheets with approximately a one pound coat weight difference. Coating with the Keegan coater though increased the coat weight only one tenth of a pound, so most of this discussion will result from comparing the results of the Keegan coater tests.

Gloss values tended to increase when coating at a low percent solids. It would be expected that with more water being present in low solids coating, more binder migration should take place. Migration to the surface of coating should increase therefore decreasing the gloss values.

The K & N ink and strength tests tend to prove this out.



K & N ink value increased slightly due to more migration of water to the surface and substrate. I.G.T. Pick and TTS values show the same general trend.

One of the problems involved here is that the spread of % concentrations were not large enough to show a definite course which was or should have been proven by these tests.

#### Varying Adhesive Levels (Table I Column 4)

From the test results of this section of the experiment it is shown that more binder migration occurs at lower adhesive levels and higher strength values are obtained when more adhesive is used.

Gloss values show that replacement of clay by adhesive will lower the gloss of the coating. There are fewer particles of clay to increase gloss whereas there are more adhesive particles which cause a duller gloss.

K & N ink and smoothness values give the overall picture of migration and level of adhesive used. When using low levels of adhesive the K & N ink test values show a considerable jump in ink receptivity. The adhesive needed to prevent the oil from penetrating is evenly distributed throughout the coating and there is just not enough of adhesive present to do the job. As the adhesive level is increased more adhesive is present to hinder penetration into the coating providing for lower K & N ink values.

The strength tests show that the more adhesive present the greater degrees of strength present. For I.G.T. Pick the more adhesive present the more bonds present to increase the strength of coating throughout. TTS results show that an increase in adhesive does not necessarily give an overall total increase in strength. TTS shows that an infrared type of drying method does essentially

prevent binder migration. Infrared drying does heat the web evenly throughout which helps in keeping the strength of the coating even throughout.

### CONCLUSIONS

1. To obtain higher gloss values Penford Gum starches in the lower viscosity range should be used.
2. Strength value between P.G.250 and P.G.290 are essentially the same. Viscosity being the major difference.
3. Heating of the web evenly throughout by oven drying or infrared methods will decrease binder migration and allow better gloss, K & N ink and TTS values.
4. TTS can be used as a test which could give correlations for the amount and direction of binder migration.
5. Increasing adhesive level concentration in the coating will decrease gloss and K & N ink values but will increase the strength properties of the coating.

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## FUTURE RESEARCH

Test methods used in this study do not give conclusive or obvious answers as to where or how much binder migration has taken place. If one was to repeat a few of the drying conditions and add just one more test to those already taken much more could be proven or disproven about binder migration.

This test would be on infrared absorption spectra. It would involve cutting the coating into very fine layers and processing the layers through an infrared machine. Quantities of binder present at certain levels would then be known and could then be related to other tests to compare with the validity of their results.